HOW TO USE MULTIMETER

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1. GENERAL

Electricity is absolutely necessary for an automobile. It is indispensable when the engine is started, the air fuel mixture is ignited and exploded, the head lights are turned on, or the various kinds of electronic control systems are operated. Electricity, as a matter of fact, performs really significant roles. Still, the voltage and current by which electricity is measured cannot be seen directly. How, then can such things be observed with the naked eye? Voltage, current, plus resistance, can all become observable if a multimeter is used properly.

Multimeters are available in two typos according to the way the reading is presented; an analog multimeter uses a pointer to indicate a value and a digital multimeter gives a numeric value.
Analog and digital multimeters have their good and bad points.

**Analog Multimeter**

**Good Points**
1. Continuous movement of the pointer permits monitoring of how the value changes.

**Bad Points**
1. In certain ranges the indicated value may differ widely from the actual value.
2. The use of many scales on the same instrument can cause confusion.
3. When resistance is to be measured, an 0Ω adjustment is necessary each time the range is changed.
4. The polarities of the test leads must be used correctly. Otherwise reverse movement of the pointer can damage an analog multimeter.

It is therefore necessary to use each type to its best advantage.

**Digital Multimeter**

**Good Points**
1. Generally provides high accuracy.
2. When the value is to be read, it is not necessary to convert the indicated value, i.e. it allows the value to be directly read.
3. Each of the voltage ranges provides high internal resistance that are constant in value. Therefore, the low voltage range also provides high internal resistance, which is a great advantage when measuring semiconductor circuits.
4. Proper polarities of the test leads do not cause concern. If the polarities are reversed, a "-" indication is displayed, clearly revealing that the polarities are reversed.

Both analog and digital multimeters are internally so complex that they cannot be readily explained in simple terms. Here is a brief account of how they are basically constructed. For further details, refer to Chapters 7 and 8.

**Analog Multimeter**
An analog multimeter is essentially a DC ammeter. How does it measure an electric current? An electric current may be compared to a water current.

![Diagram of Analog Multimeter](image)

Measuring some of the water current provides a way to measure the flow rate of the entire water current.

**Digital Multimeter**
A digital multimeter is essentially a voltage comparator. How does it measure voltage? Measurement of voltage may be compared to measurement of water pressure by comparing the amounts of water.

![Diagram of Digital Multimeter](image)

First let water with an unknown water pressure \( P \) flow into the measuring cylinder during reference Period \( (T_s) \). Then let water with reference water pressure \( P_s \) flow into an identical cylinder until the weight of both cylinders balance. By measuring the time required before they balance, the unknown water pressure can be calculated.

\[
P = P_s \times \frac{T_s}{T_r}
\]
2. ANALOG MULTIMETER

The main parts of an analog multimeter are briefly described below.

1. METER SECTION

The meter section consists of scales and a pointer. The degree of deflection of the pointer enables the voltage value, current value and resistance value to be read. There are various kinds of scales. Check the position of the range selector described below and read the scale that matches the position of the range selector.
- DC V: Direct current voltage
- AC V: Alternating current voltage
- DC A: Direct current current
- Ω: Resistance

2. RANGE SELECTOR

Select one of the measuring ranges of DC voltage (DC V), AC voltage (AC V), DC current (DC A) or resistance (Ω) by rotating this selector. In each of the ranges a finer range more suitable for measuring the desired value can be selected.

3. ZERO POSITION ADJUSTER

If the pointer is not at the zero position before a measurement it can be adjusted to the zero position using the zero position adjuster.
4. **0Ω ADJUSTER**

After selection of any of the positions (x1, x100, x1 K, etc.) of the resistance range by the range selector for measurement of a resistance, put both test leads in contact with each other and adjust the pointer to the 0Ω position at this time.

5. **MEASURING TERMINALS**

The measuring terminals are the + and - (COM) terminals. Connect the red test lead to the + terminal and connect black test lead to the - (COM) terminal.

**MEASURING SEQUENCE**

A general measuring sequence is shown below. Detailed procedures for measurement of a DC voltage, AC voltage, DC current and resistance are described separately.

1. **ADJUSTMENT OF ZERO POSITION**

Before using the multimeter, place it in its level position and check that the pointer is in the "0" position at the extreme left of the scales. If the pointer is not at the zero position, adjust it by using the zero position adjuster.

When an indication on the meter is read, read it with your eye directly above the pointer.
2. **SELECTION OF MEASURING RANGE**

Select a measuring range (voltage, current or resistance) and set the range selector to the position that matches the type and anticipated magnitude of the measurement value.

![Diagram of range selector](image)

3. **CONNECTION OF TEST LEADS**

Securely connect the red and black test leads to the + and - (COM) terminals respectively, of the multimeter.

Then connect the probes at the other ends of the test leads to the circuit to be measured. Note that the way the probes are connected varies according to different measuring ranges.

![Diagram of test lead connections](image)
4. **READING OF INDICATION**

Read the indication of the scale corresponding to the measuring range selected by the range selector.

![Scale Diagram](image)

**POINTS TO NOTE WHEN USING AN ANALOG MULTIMETER**

1. **CONFIRMATION OF MEASURING RANGE**

Most of the problems with this type of multimeter are caused by over current or by allowing the multimeter to fall. To prevent an over current, it is only necessary to confirm the measuring range. Application of a voltage should be avoided especially when the multimeter is in a current or resistance range has low internal resistance.
2. CONNECTION OF TEST LEADS

The two test leads colored red and black, are paired. Connect the red test lead to the + measuring terminal and connect the black test lead to the - (COM) measuring terminal.

When the probes of both test leads are connected to the circuit to be measured, pay special attention to their polarities.

3. MEASUREMENT OF A VOLTAGE OR CURRENT WHOSE VALUE IS UNKNOWN

To prevent an over current, first measure the voltage or current in the highest range to find the approximate value of the voltage or current. Select the optimum range accordingly.

4. CHANGEOVER OF MEASURING RANGES

If you want to change ranges during a measurement, make sure that at least one of the test leads is disconnected before changing the range selector position. If ranges are changed with the voltage applied, the multimeter could be damaged by spark, etc.

5. MISCELLANEOUS

- Avoid vibration and shock.
- Avoid high temperatures, high humidity, and direct exposure to the sun.
3. DIGITAL MULTIMETER

The major parts of a digital multimeter are briefly described below.

1. LCD METER SECTION
The LCD meter section indicates a number and a polarity.
If the polarity of the input is negative, that display section presents a "-" indication. If an excessive input is applied, it indicates

2. RANGE SELECTOR
Two types of range selectors are available, types 1 and 11.
- Type 1 has the same range selector that is used for the analog multimeter. It changes measuring ranges as well as measuring functions.
- Type 11 changes functions only (i.e., the measuring ranges are automatically changed according to the magnitude of the quantity being measured.)

3. POWER SWITCH
The power switch is used to turn the power supply of the multimeter on and off. Generally the power switch is separate from the range selector. This is because a digital multimeter, unlike an analog multimeter, requires a power supply for the LCD meter and internal circuits.

4. HOLD BUTTON
Not all multimeters have this button. When a digital multimeter is used for measuring a value that makes minute changes, you cannot read the display because it changes too rapidly. In such a case press this button to put the display on hold to read the value. The display will remain while the button is being pressed.
5. **MEASURING TERMINALS**

The number and kind of terminals generally vary according to the model.

Whereas the black test lead is always connected to the - (COM) terminal, the red test lead should be connected to the terminal that matches the position where the range selector is placed.

![Image of terminal connections]

**MEASURING SEQUENCE**

A general measuring sequence's shown below. Practical procedures for measurement of a DC voltage, AC voltage, DC current and resistance are described individually.

1. **POWER SUPPLY**
   
   Set the POWER switch at ON.

![Image of power switch]
2. **SELECTION OF MEASURING RANGE**

Select a desired function (voltage, current or resistance) and select a measuring range that matches the anticipated magnitude of the function to be measured.

3. **CONNECTION OF TEST LEADS**

Securely insert the black test lead into the - (COM) terminal of the multimeter. Insert the red test lead into the terminal that matches the measuring range.

4. **READING OF INDICATION**

An indication is presented either with or without the unit of measurement. Generally, multimeter with the automatic range changeover capability indicates the unit as well as the measured value. The value indicated by the LCD meter section can be read directly.

A multimeter without the automatic range changeover capability does not indicate the unit. When an indication is read, therefore multiply the indicated value by the unit of the, range selected by the range selector.
POINTS TO NOTE WHEN USING A DIGITAL MULTIMETER

1. CONFIRMATION OF MEASURING RANGE
   As in the case of the analog multimeter, avoid excessive input. Maximum input differs according to the function and range. Make sure that any input in excess of the maximum allowable quantity in each range is never applied.

2. OVERINPUT INDICATION
   If an excessive input is applied, an over input indication is presented. The over input indication is or which appears alone at the largest digit position of the display.
   In any range except the ohm range, avoid using the multimeter in conditions where an over input indication appears.

3. CONFIRMATION OF MEASURING TERMINALS
   The terminals differ according to the model. When the test leads are connected, be careful to select the right terminals.

4. CHANGEOVER OF RANGE SELECTOR
   When the range selector is to be changed during a measurement, make. Sure that at least one of the test leads has been disconnected before hand from the circuit being measured.
5. **POWER SUPPLY**
A digital multimeter, unlike an analog multimeter, requires that its power supply be turned on before a measurement.

6. **MISCELLANEOUS**
- Avoid vibrations and shocks.
- Avoid high temperatures, high humidities, and direct exposure to the sun.

4. **MEASUREMENT OF DC VOLTAGE**

   **Analog multimeter**
   
   1) Move the range selector to the proper range of DC V.
   2) Connect the multimeter in parallel with the circuit to be measured.
   3) Read the deflection of the pointer on the DC V scale.

   *(Examples of Readings)*

   1,000V range: Multiply the indication on the 0 - 10 scale by 100 to obtain the actual voltage.
   500V range: Multiply the indication on the 0 - 50 scale by 10 to obtain the actual voltage.
   250V range: Directly read the indication on the 0-250 scale.
   50V range: Directly read the indication on the 0-50 scale.
   10V range: Directly read the indication on the 0-10 scale.
2.5V range: Multiply the indication on the 0 - 250 scale by 0.01 to obtain the actual voltage.
0.25V range: Multiply the indication on the 0 - 250 scale by 0.001 to obtain the actual voltage.

Digital multimeter

1) Set the POWER switch at ON.
2) Move the range selector to the proper DC V range.
3) Connect the multimeter in parallel with the Circuit to be measured.
4) Pay attention to the position of the decimal point when reading the indication.

MEASUREMENT OF VOLTAGE DROP

When an electric current is caused to flow through a resistor, a potential difference (voltage) occurs across the resistor. In other words, as current flows from point a in to point b to point c to point d, the voltage gradually falls due to the resistances. Since the combined resistance is 48Ω (= 12Ω + 24Ω + 12Ω), current is 0.25A. The voltage drops caused by the lamps and resistor occur as shown below.

Lamp A ....... 12Ω × 0.25A = 3V (VA)
Resistor B .... 24Ω × 0.25A = 6V (VB)
Lamp C ....... 12Ω × 0.25A = 3V (VC)
If the voltage is measured with a multimeter as shown, then a potential diagram can be made such as the one shown. If there is an open circuit at point b, the potential diagram will be as shown. If there is a short circuit at point c, the potential diagram will be as shown.

Reference

INTERNAL RESISTANCE OF MULTIMETER AND ITS EFFECTS ON A CIRCUIT

The voltage drops caused by resistors R1 and R2 may be calculated as shown below.

\[ V_1 = 1 \times R_1 = \frac{12}{300 + 200} \times 300 = 7.2V \]

\[ V_2 = 1 \times R_2 = \frac{12}{300 + 200} \times 200 = 4.8V \]
If a voltage drop is measured by using a multimeter as shown, some changes are caused by the internal resistance of the multimeter. The change varies according to the internal resistance.

1. DIGITAL MULTIMETER WITH AN INTERNAL RESISTANCE OF 10MΩ (CONSTANT)
   The combined resistance of 10MΩ and 300kΩ connected in parallel is 291kΩ. The Multimeter's Indication, therefore is:
   
   \[ V' = I' \times 291 = \frac{12}{291 + 200} \times 291 = 7.1V \]

2. ANALOG MULTIMETER WITH AN INPUT IMPEDANCE* OF 2KΩ/V
   (In the 0 - 10V DCV range, the internal resistance is 2kΩ/V x 10V = 20kΩ.)
   
   The combined resistance of 20kΩ and 300kΩ connected in parallel is 18.75kΩ.
   
   The multimeter’s indication (V'1), therefore is:
   
   \[ V'1 = I' \times 18.75 = \frac{12}{18.75 + 200} \times 18.75 = 1V \]
3. **ANALOG MULTIMETER WITH AN INPUT IMPEDANCE* OF 20kΩ/V**

(In the 0 - 10V DC V range, the internal resistance is 20kΩ/V x 10V = 200kΩ.)
The combined resistance of 200kΩ and 300kΩ connected in parallel is 120kΩ.
The multimeter's indication (V'1), therefore is:

\[ V'1 = I' \times 120 = \frac{12}{120 + 200} \times 120 = 4.5V \]

Thus it can been seen that the voltage indicated by one type of multimeter is
different from the voltage indicated by another type.

When a voltage needs to be read accurately the use of a digital multimeter is
recommended.

If an analog multimeter with a very low input impedance is used as shown, the
external device and the multimeter will be connected in parallel, and flow of an
excessive current could damage transistor Tr in the electronic control unit.
Avoid using such a multimeter in measuring the voltage across the terminals
of an electronic control unit.

(An input impedance of 1kΩ at least is required.)
MEASUREMENT OF AC VOLTAGE

Analog multimeter

1) Move the range selector to the proper AC V range.

2) Connect the multimeter in parallel with the circuit to be measured.

3) Read the deflection of the pointer on an AC V scale.

(Examples of Readings)

1,000V range: Multiply the indication on the 0 - 10 scale by 100 to obtain the actual voltage.

500V range: Multiply the indication on the 0 - 50 scale by 10 to obtain the actual voltage.

250V range: Directly read the indication on the 0-250 scale.

50V range: Directly read the indication on the 0-50 scale.

10V range: Directly read the indication on the 0-10 scale.

2.5V range: Multiply the indication on the 0 - 250 scale by 0.01 to obtain the actual voltage.

0.25V range: Multiply the indication on the 0 - 250 scale by 0.001 to obtain the actual voltage.

Digital multimeter

1) Set the POWER switch at ON.

2) Move the range selector to the proper AC V range.

3) Connect the multimeter in parallel with the circuit to be measured.

4) Pay attention the position of the decimal point when reading the indication.
MEASUREMENT OF DC CURRENT

Analog multimeter
1) Move the range selector to the proper DC A range.
2) Cut the circuit to be measured and connect the black test lead to the low potential side and connect the red test lead to the high potential side.
3) Read the deflection of the pointer on a DC A scale.

(Examples of Readings)

0.5A range: Multiply the indication on the 0 - 50 scale by 0.01 to obtain the actual current in amperes.
25mA range: Multiply the indication on the 0 - 250 scale by 0.1 to obtain the actual current in mA.
50µA range: Directly read the indication in µA on the 0 - 50 scale.

Digital multimeter
1) Set the POWER switch at ON
2) Cut the circuit to be measured, connect the black test lead to the low potential side and connect the red test lead to the high potential side.
3) Pay attention to the position of the decimal point when reading the indication.

MEASUREMENT OF RESISTANCE
Analog multimeter
1) Move the range selector to the proper Ω range.
2) Short the red and black test leads and move the 0Ω adjuster so that the pointer reads 0Ω. (If the pointer cannot be moved to the 0Ω position by rotating the 0Ω adjuster, replace the unit battery with a new one.)
3) Connect the test leads to the resistor to be measured.
4) Read the deflection of the pointer on the scale.
(Examples of Readings)

x1 range: Directly read the indication.
x10 range: Multiply the indication by 10 to obtain the actual resistance.
x100 range: Multiply the indication by 100 to obtain the actual resistance.

NOTE:
- In most multimeters the electric current flows from the (-) terminal to the (+) terminal. When a semiconductor is measured, pay attention to the direction of flow.

Digital multimeter

1) Set the POWER switch at ON
2) Move the range selector to the proper Ω range.
3) Connect the test leads to the resistor to be measured.
4) Pay attention to the position of the decimal point when reading the indication.